Pre-restoration studies of the Upper Big Darby Watershed: Preliminary results (1st year – 2000)

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Introduction

Previous research on the Big Darby watershed (EPA, 1994; EPA, 1996; TNC, 1996) indicated changes in land use within the Big Darby Creek watershed might, over time, affect stream ecosystem attributes such as habitat and water quality of this highly valued stream in central Ohio. The Ohio Chapter of The Nature Conservancy (TNC), in collaboration with the U.S. Army Corps of Engineers (USACOE) and The Ohio State University, has initiated a study of the restoration potential for the upper headwaters of Big Darby Creek watershed. The project proposed is intended to support the adaptive management process of Big Darby Creek in three overlapping ways: 1) to protect prominent bio-diversity composition, structure and function with population and communities; 2) to restore/maintain the natural processes and habitats; and 3) to have effective actions aimed at abating threats to the ecosystem.

Th preliminary research reported here for 2000 is part of that effort by The Ohio State University wetland program. Discussions on the improvement of the Upper Big Darby have included discussions of a wetland or series of wetlands created or restored in this upper watershed to improve water quality, ameliorate flood peaks, and provide habitat. This restoration will need both pre- and post-restoration monitoring to determine the effectiveness of the restoration projects.

Materials and Methods

Upper Big Darby

The study area, with an area of 102 km^2, is located at the headwater of Big Darby Creek in central Ohio (Figure 1). It is contained within three counties in Ohio: Logan, Union, and Champaign. Big Darby Creek flows into the Scioto River which in turn flows into the Ohio River.

The geology of the Big Darby Creek watershed was defined from the glacial advances and retreats of the Wisconsin glaciation dating back 15,500 to 17,00 years. The upper most bedrock units are the Silurian-Devonian limestones and dolomites. The average slope of the upper Big Darby is 6.5%, where the terrain is flat to gently rolling with more than 90% of the land having slope less than 6% at the basin. Soils are associated with silty clay loams with moderatedly slow to slow subsoil permeability and low to moderate erosion hazards (USEPA, 1994).

Prior to European/American settlement, the Big Darby Creek watershed consisted primarily of wet prairies in the flat and upland regions and mixed oak forests and savannahs on its gently sloping knolls (TNC, 1999). The first permanent settlers, Josua and James Ewing, came to Union County in 1798 (Ohio Historical Society, 2001). Since then the Big Darby Creek watershed has been draining, and today more than 90% of its wetlands have been converted to agricultural fields and other development (TNC, 1999). An example, “Bear Swamp,” formerly known as the “ flat woods,” was covered with a very level and dense growth of timber (Ohio Historical Society, 2001). Presently, the upper watershed of the Big Darby is a highly productive agricultural area with a diverse range of land use including cropping with a corn-soybean crop rotation, livestock pasturing, forest, discrete woodlots and urban/residential use (TNC, 1999). It also encompasses a major industrial development by Honda Motors.

Precipitation data are made available from Honda at their facility in the watershed. One USGS stream gauge station (http://water.usgs.gov/oh/nwis/uv?03230500; Latitude 39^{o}42’02”, longitude 83^{o}06’37”) is located downstream on Big Darby Creek in Pickaway County and provides a long-term (1921-1999) daily surface discharge.

Stream Flow and Water Quality Sampling

One stream gauging station with an Ott Thalimedes data logger was installed at station 1 (Figure 2) in August 2000. Water was analyzed weekly from July 19, 2000 to Nov. 20, 2000 for temperature, dissolved oxygen, conductivity, and pH at 8 stations (Figure 1) were manually monitor on a weekly basis with the YSI 610 sonde. One 1000 ml bottle surface water sample was collected weekly for nutrient analyses.

Sample Analysis

Standard Methods for the Examination of Water and Wastewater, 20th Edition (APHA, 1996) and EPA Methods for Chemical Analysis of Water and Wastes (USEPA, 1983) were followed for nutrient analyses. Total phosphorus, soluble reactive phosphorus, and nitrate + nitrite were analyzed with a Lachat QuikChem IV automated system and Lachat methods (USEPA, 1983). Total phosphorus samples were first digested by adding 0.5 ml of 5.6N H_2SO_4 and 0.2 g NH_3SO_4 to 25 ml of sample. Samples were exposed to a heated and pressurized environment for 30 minutes in an

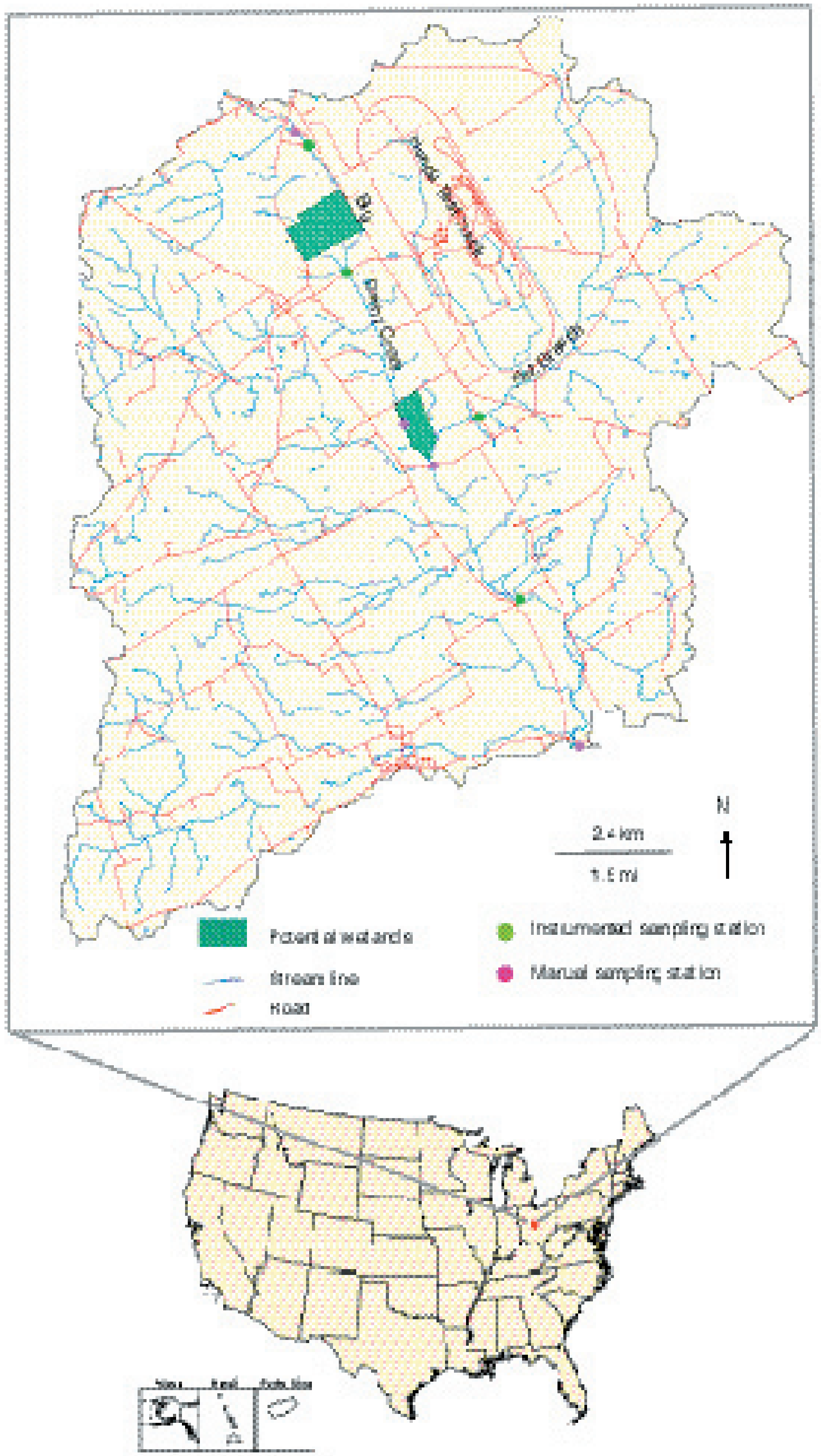

Figure 1. Study area in Upper Big Darby Creek watershed, showing sampling stations and potential locations of wetland creation/restoration.

Figure 2. Stream gauging station at site 1.

autoclave. Nitrate+nitrate, run on the Lachat QuikChem IV automated system, used the cadmium reduction method. Turbidity was measured with a Hach turbidimeter in the laboratory.

GIS Analysis

GIS layers for the study area were extracted from Geographic Information Systems OhioDas at http://www.geodata.gis.state.oh.us/dlg/index.htm, with a scale of 1:24,000, and projected by Universal Transverse Mercator (UTM). A Digital Elevation Model (DEM) was generated by hypsography layer and used to create the research area boundary at the watershed. The GIS layers were created by a series of polygonal layers using ARC/INFO GIS software (ESRI, 2000). A semi-variogram—kriging approach (Equation 1) was used to estimate uncertainty of spatial variance (distance between the two sample sites) of water quality parameters (mean of temperature, dissolved oxygen, both total phosphorus and soluble reactive phosphorus, and nitrate + nitrate).

$$\gamma(h) = \frac{1}{2n}\sum_{i=1}^{n}\{Z(x_i) - Z(x_i + h)\}^2 \qquad 0 < h \le a \qquad (1)$$

where

x_i = value of sample parameter;
n =the number of pairs of sample points separated by distance h.

Semi-variogram models (spherical (Fig. 3), exponential, Gaussian and linear, Equations 2-5) were used to define model uncertainty in terms of the average squared difference y(h) in z value between pairs of input sample points separated by h.

spherical

$$\gamma(h) = c_0 + c\left(\frac{3h}{2a} - \frac{1}{2}\left(\frac{h}{a}\right)^3\right)$$

and $\gamma(h) = c_0 + c$ h>a (2)

exponential

$$\gamma(h) = c_0 + c\left\{1 - \exp\left[\frac{-h}{r}\right]\right\}$$ h>a (3)

Gaussian

$$\gamma(h) = c_0 + c\left\{1 - \exp\left[\frac{h^2}{r^2}\right]\right\}$$ h>a (4)

linear

$$\gamma(h) = c_0 + c\left[\frac{h}{a}\right]$$ (5)

and $\gamma(h) = c_0 + c$ h>a

for all $\gamma(0) = 0$

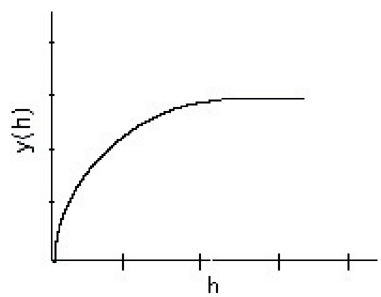

Figure 3. Spherical method of kriging.

Results and Discussion

Precipitation and Streamflow

Figure 4 presents cumulative rainfall and its monthly percentage in the study area during 2000. About 25% of precipition occurs in April and May duirng periods of low evapotranspiration. About 22% of the precipitation occurs in August, and September, but mainly through convective storms and much of that precipitation is adsorbed in the watershed though soil storage and lost through evapotransporation then.

Annual mean streamflow for Big Darby Creek from 1922 –1999 is shown in Figure 5. The wettest years were 1929, 1979, 1990, 1993, and 1996. Drier years were 1925, 1934, 1941, 1953, 1954, and 1987. Sixty percent of the wet years have occurred since 1990 while there has been no dry year since 1987. The average monthly flow of the Big Darby is shown in Figure 6. Since our water quality sampling was in September through November 2000, we were sampling, for the most part, the low-flow conditions of the Big Darby (see Water Quality below).

Figure 7 shows hourly water level data at Station 1 for

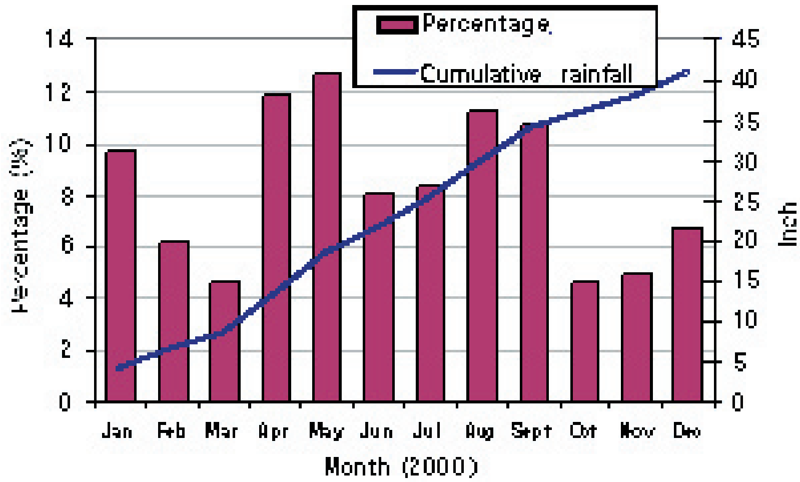

Figure 4. Rainfall data from Union County (Honda Inc. weather station), January to December 2000.

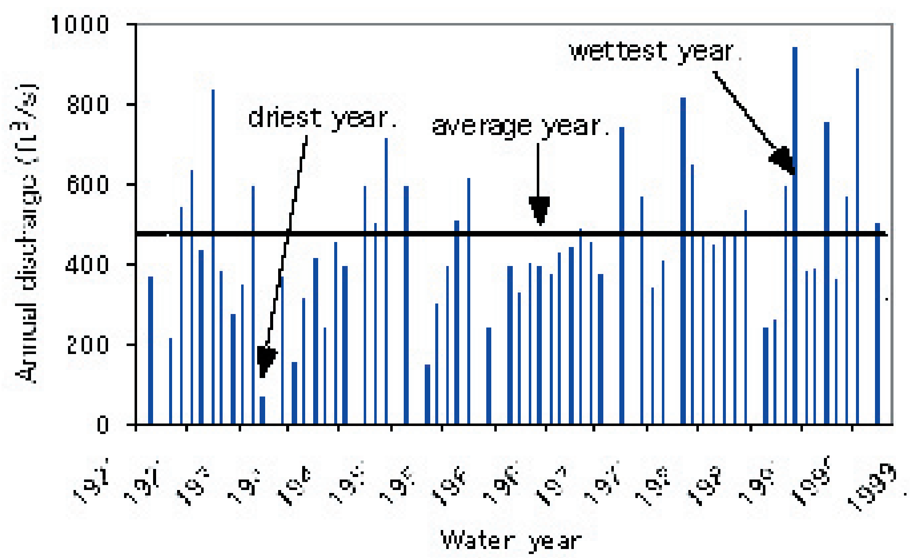

Figure 5. Calendar year streamflow of Big Darby Creek from1922 to 1999 (USGS station 03230500, Darbyville, OH)

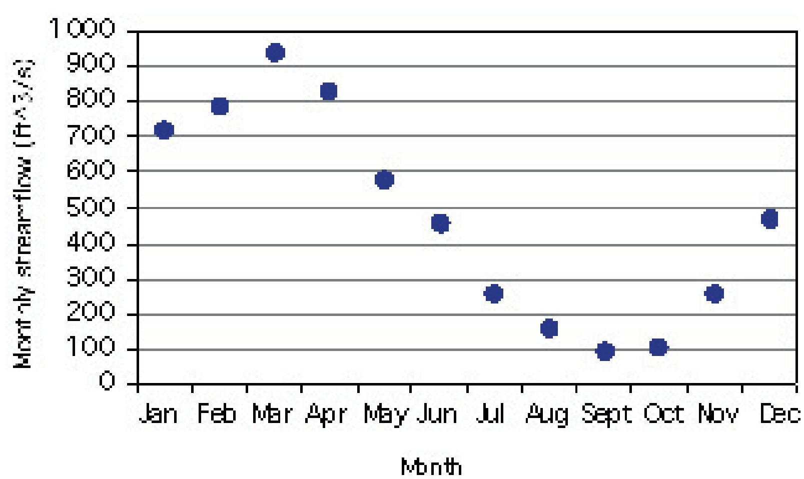

Figure 6. Mean of monthly streamflows of Big Darby Creek, 1939 to 1998 (USGS station 03230500 at Darbyville, OH)

September 1 2000 (the date when the gauging station was installed) to the end of December 2000. [After calibration, this water level data, along with similar data from 3 new stations being installed in 2001will be translated to flow measurements.] Few storm events occurred during this short period althugh one major storm event did occur on September 23, 2000 and made the gauging height rise from 1.18 ft to 2.08 ft. Flooding in September is not normal as this is generally the period of lowest discharge in the Big Darby (Figure 6).

Water Quality

Table 1 and Figure 8 illustrate initial results of weekly water quality results for each of our 8 monitoring stations shown in Figure 1 for the period July 19 throughNovember 20, 2000). Patterns of temperature, DO, conductivity and pH (Figure 8) are consistent spatially (Figure 8). Turbidity, soluble reactive phosphorus, total phosphorus, and nitrates showed a less consistent pattern from station to station (Figure 8). Total phosphorus of 525 μg-P/l on Nov. 10, 2000 at Station 3 (Flat Branch), and nitrate-nitrogen concentrations of 17.9 mg-N/l on July 25, 2000 at Station 3 and 14.4 mg-N/l at Station 1 are unusually high. Table 2 presents results of paired t-tests with Station 0 (most upstream site on Big Darby) as the reference site. By Station 2a, just upstream of the confluence of the Big Darby with Flat Branch, dissolved oxygen and pH were statistically higher (these are manual measurements generally made in the late afternoon) and soluble reactive phosphorus had increased from 9 to 83μg-P/l. At that point the fairly polluted Flat Branch enters Big Darby Creek, and water quality at Station 4, downstream of the confluence, has statistically higher temperature (15.6 to 16.9 °C), pH (7.8 to 8.0), turbidity (36 to 55 NTU), soluble reactive phosphorus (9 to 51 μg-P/l), and total phosphorus (60 to 183 μg-P/). Conductivity (803 to 639 μmohm/cm) was statistically lower from Station 0 to 4, as the stream is more influenced by surface runoffdownstream and groundwater upstream. By the time Big Darby Creek passes the confluence with the Flat Branch is it sigificantly polluted with phosphrous and sediments. There is not an obvious trend of increasing nitrates over that reach, with highest average concentrations seen at both Stations 1 and 5 on the Darby (2.3 mg-N/L) and the Flat Branch (2.2 mg-N/L). All of these concentrations of sediments (turbidity), phosphorus, and nitrate-nitrogen could be significantly reduced by well-placed wetlands.

GIS analysis

Figure 9 shows DEM (50 m grid) for the study area with the lowest elevation of 300 m to the highest elevation of 465 m. Land use layer source was based on the year

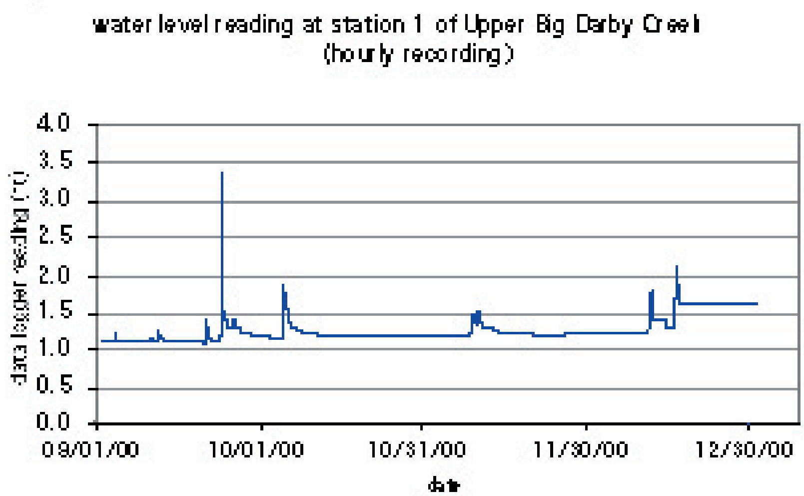

Figure 7. Stage of Big Darby Creek at Station 1, September 1 through December 31, 2000.

Table 1. Average ± standard error of selected Water quality of Upper Big Darby Creek, July through November 2000

Site	Temp °C	DO mg/L	Conductivity μS/cm	pH	Turbidity NTU	SRP μg-P/l	Total P μg-P/L	NO_3-N mg-N/l
0	15.6±0.9	8.5±1.0	803±46	7.82±0.09	36±18	8.7±1.0	60.2±20	1.91±0.61
1	16.8±1.3	10.8±1.3	828±48	7.95±0.13	47±17	9.4±2.3	77.4±20	2.31±1.13
2	15.5±0.9	9.5±1.1	727±42	7.84±0.07	43±19	15.1±7.2	95.2±30	1.45±0.43
2A	16.3±1.0	10.4±1.1	744±44	8.12±0.06	38±14	82.6±15.3	125±30	1.91±0.61
3	17.7±1.3	8.9±1.0	566±42	7.91±0.10	66±11	35.5±10.2	151±40	2.21±1.32
4	16.9±1.1	9.6±1.0	639±51	8.03±0.04	55±16	50.8±8.6	183±40	1.43±0.51
5	17.2±1.2	10.1±1.3	621±45	8.12±0.06	32±10	37.2±10.9	87±30	2.33±0.54

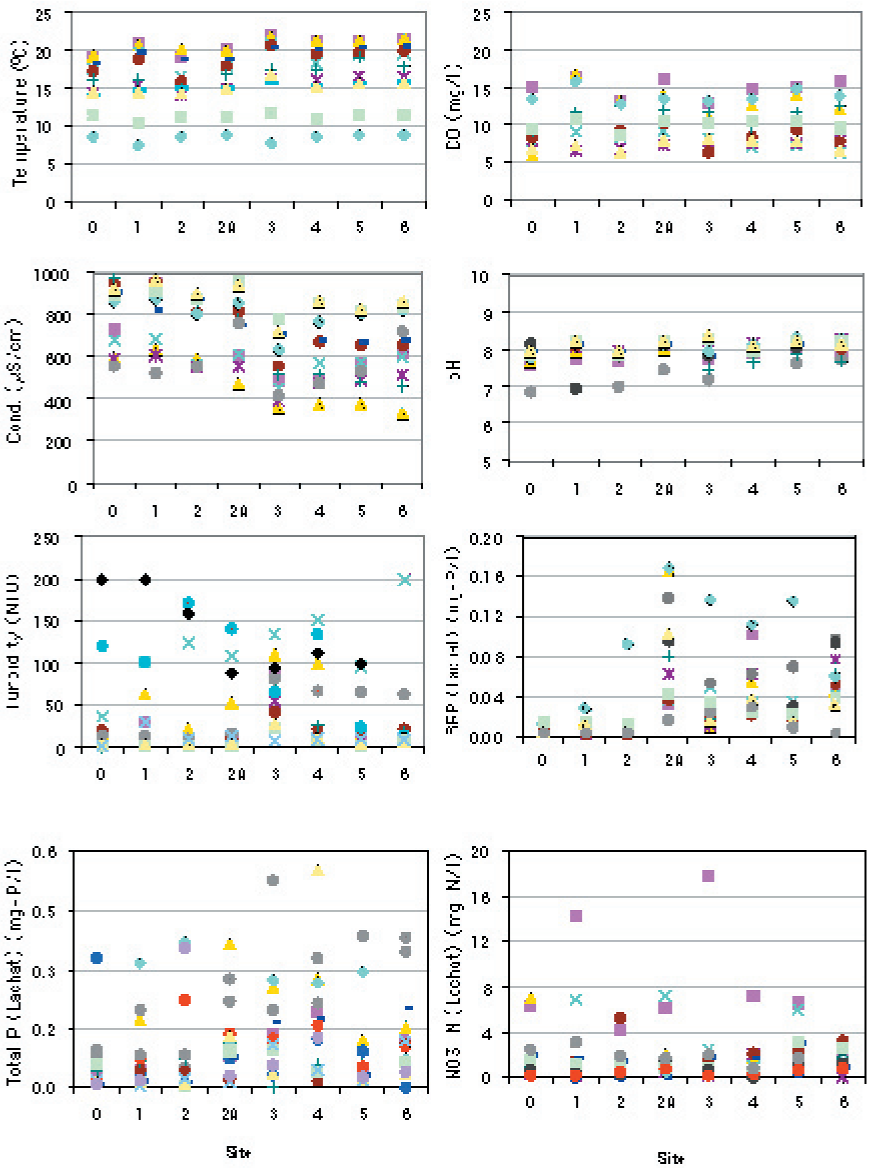

Figure 8. Water quality parameters for each monitoring site in Upper Big Darby Creek, July to November 2000.

Table 2. Paired t-test results for water quality parameters, with Station 0 as a reference, and μ=0.05.

			Stations			
Parameters	1	2	2A	3	4	5
Temperature	0.036*	0.486	0.207	0.001*	0.005*	0.443
DO	0.032*	0.263	0.023*	0.519	0.127	0.082
Conductivity	0.246	0.002*	0.109	0.000*	0.001*	0.002*
pH	0.308	0.561	0.000*	0.337	0.036*	0.002*
Turbidity	0.139	0.465	0.395	0.202	0.014*	0.002*
SRP	0.925	0.390	0.000*	0.001*	0.044*	0.936
Total P	0.632	0.462	0.097	0.060	0.023*	0.463
NO3-N	0.690	0.465	0.492	0.175	0.205	0.828

* significantly different from Station 1 at μ<0.05

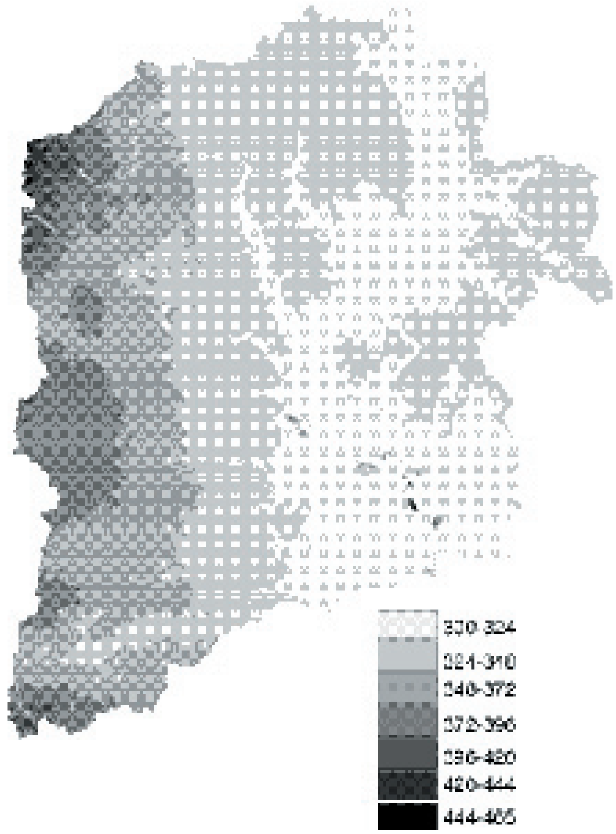

Figure 9. Digital Elevation Model (50m grid) for the study area

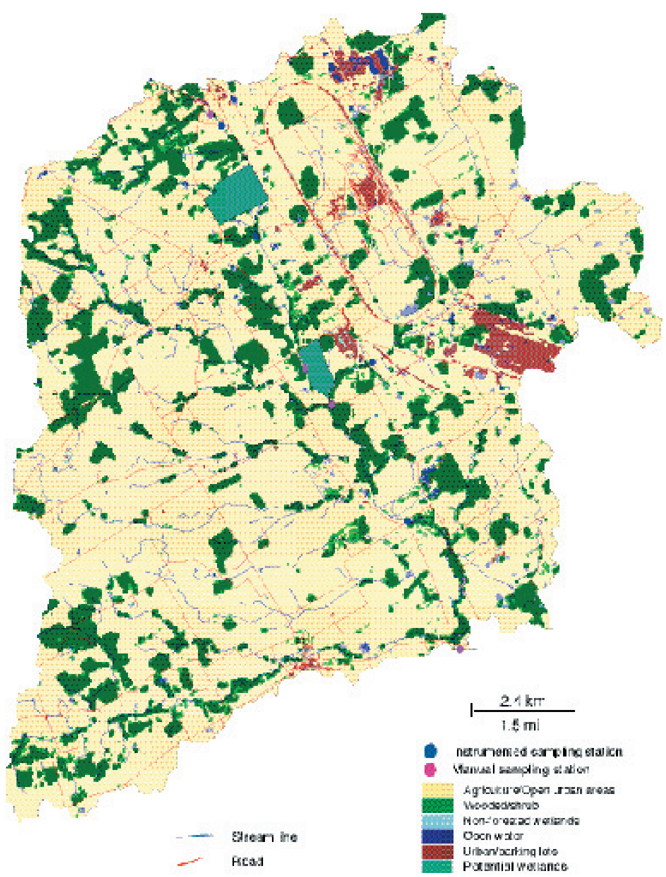

Figure 10. Land use for the study area in 1994

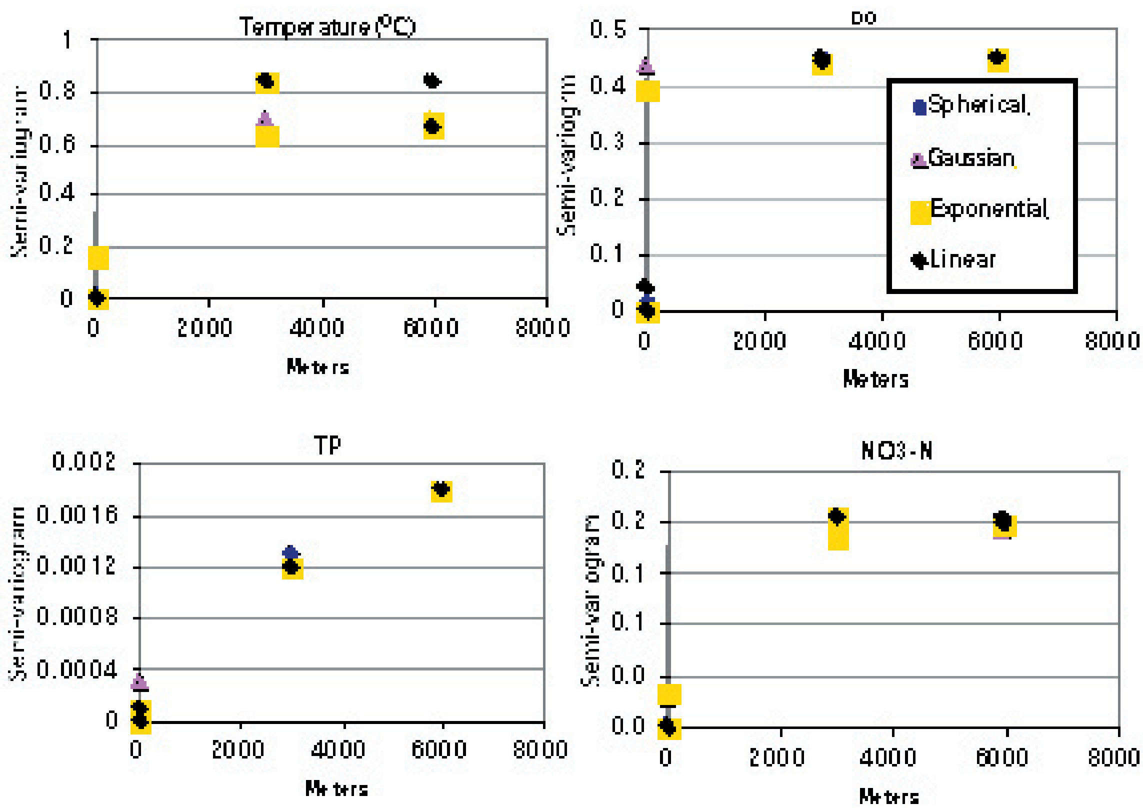

Figure 11. Uncertainty of the Krieging modeling approach.

1994 (Figure 10), and the majority of the study area is used for cropping. It is comprised of 96.4% agriculture, 2.8% urban, 0.8% wooded/shrub, 0.08% non-forested wetland and 0.03% open water. Initial results of kriging (Figure 11) showed uncertainty of the modeling approaches, because of limited sampling points.

Future Research

Weekly water quality sampling continued in mid-2001 with the renewal of this study through the contract with USACOE. Three additional flow gauging stations and 3 auto-sampler are being added at instrumented sampling stations. Relationships between nutrient dynamics will be established for both peak and low flow. We will also analyze monthly samples for selected metal element. This study will continue through August 2004. Hydrologic, water quality, stream biology data, and GIS map analysis will enable us to suggest basin restoration that will enhance downstream water quality and hence biological integrety of the Big Darby watershed.

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